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The evolving theory of quality management: The role of Six Sigma

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Abstract

While Six Sigma is increasingly implemented in industry, little academic research has been done on Six Sigma and its influence on quality management theory and application. There is a criticism that Six Sigma simply puts traditional quality management practices in a new package. To investigate this issue and the role of Six Sigma in quality management, this study reviewed both the traditional quality management and Six Sigma literatures and identified three new practices that are critical for implementing Six Sigma's concept and method in an organization. These practices are referred to as: Six Sigma role structure, Six Sigma structured improvement procedure, and Six Sigma focus on metrics. A research model and survey instrument were developed to investigate how these Six Sigma practices integrate with seven traditional quality management practices to affect quality performance and business performance. Test results based on a sample of 226 US manufacturing plants revealed that the three Six Sigma practices are distinct practices from traditional quality management practices, and that they complement the traditional quality management practices in improving performance. The implications of the findings for researchers and practitioners are discussed and further research directions are offered.
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1. Introduction

Quality management (QM) has developed into a mature field with sound definitional and conceptual foundations (Sousa and Voss, 2002), but new QM methods continue to grow. For example, Six Sigma, which is ''an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates'' (Linderman et al., 2003, p. 194), generates intense interest in industry. Since its initiation at Motorola in the 1980s, many companies including GE, Honeywell, Sony, Caterpillar, and Johnson Controls have adopted Six Sigma and obtained substantial benefits (Pande et al., 2000; Snee and Hoerl, 2003). However, Six Sigma is criticized as offering nothing new and simply repackaging traditional QM practices (Clifford, 2001; Dalgleish, 2003; Stamatis, 2000). It is argued that the large returns from Six Sigma at some companies were due to the initial

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quality level of these companies being so low that anything would have drastically improved their quality (Stamatis, 2000). Although there have been numerous case studies, comprehensive discussions, books and websites addressing Six Sigma, very little scholarly research has been done on Six Sigma and its influence on quality management theory and application (Goffnett, 2004; Schroeder et al., 2005).

This study explores what is new in Six Sigma by identifying the practices that are critical for implementing Six Sigma's concept and method in an organization. It then develops a model of how the Six Sigma practices integrate with traditional QM practices to improve performance. The model was tested using survey data collected from 226 manufacturing plants in the US. The empirical findings of this study strengthen our understanding of Six Sigma's key practices and how it complements traditional QM, and provide practitioners with rigorous research-based answers about Six Sigma implementation.

2. Theoretical development

Quality management is characterized by its principles, practices, and techniques (Dean and Bowen, 1994). The principles provide general guidelines, which are implemented through the practices that are themselves supported by multiple techniques (Dean and Bowen, 1994). Empirical research that assesses QM and what constitutes QM should be conducted at the level of practices because the practices are the observable facet of QM, and it is through them that the QM implementation is accomplished and managers work to achieve quality improvements (Sousa and Voss, 2002). Accordingly, in order to study Six Sigma and its role in QM, this study focuses on identifying the practices that are distinctively associated with Six Sigma implementation and exploring their relationships with traditional QM practices.

2.1. Traditional QM practices

There is substantial agreement in the literature concerning what the key QM practices are (Sousa and Voss, 2002). In this study, we examine seven traditional QM practices that have been commonly investigated in prior empirical QM research. These practices are top management support, customer relationship, supplier relationship, workforce management, quality information, product/service design, and process management. Since the seven traditional QM practices have been extensively discussed in previous studies such as Flynn et al. (1994, 1995) and Kaynak (2003), and in Nair's (2006) meta-analysis study, we will not discuss them in detail here. Table 1 offers a brief description of the traditional QM practices as well as Six Sigma practices which are discussed next.

2.2. Six Sigma practices

Based on a review of both research studies and practitioner literature on Six Sigma, we identify three practices that are critically associated with Six Sigma implementation. These practices are Six Sigma role structure, Six Sigma structured improvement procedure, and Six Sigma focus on metrics.

2.2.1. Six Sigma role structure

Six Sigma uses a group of improvement specialists, typically referred to as champions, master black belts, black belts, and green belts (Henderson and Evans, 2000; Linderman et al., 2003). Those specialists receive intensive differentiated training that is tailored for their ranks and is designed to improve their knowledge and skills in statistical methods, project management, process design, problem-solving techniques, leadership skill, and other managerial skills (Barney, 2002a; Gowen and Tallon, 2005; Linderman et al., 2003; Snee and Hoerl, 2003). With assigning the improvement specialists to take different levels of roles and responsibilities in leading the continuous improvement efforts, the organization builds a Six Sigma role structure for quality improvement. In the Six Sigma role structure, there is a hierarchical coordination mechanism of work for quality improvement across multiple organizational levels (Sinha and Van de Ven, 2005). For example, the senior executives serve as champions for making the organization's strategic improvement plans and black belts under them lead Six Sigma projects and mentor green belts in problem solving (Barney, 2002a,b; Sinha and Van de Ven, 2005). This mechanism helps to coordinate and control work across organizational levels to ensure that the tactical tasks match with the overall business strategy (Sinha and Van de Ven, 2005).

2.2.2. Six Sigma structured improvement procedure

Six Sigma applies a structured approach to managing improvement activities, which is represented by Define–Measure–Analyze–Improve–Control (DMAIC) used in process improvement or Define–Measure–Analyze–Design–Verify (DMADV) used in product/service design improvement (Linderman et al., 2003). Both of these procedures are grounded in the classic

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Table 1
Traditional QM practices and Six Sigma practices examined in the model

Practices	Description of domain and examples of techniques
Top management support	Top management accepts responsibility for quality and is evaluated based on quality performance. Top management participates in quality improvement efforts and makes strategies and goals for quality improvement.
Customer relationship	Customer needs and expectations are assessed. Customers are involved in quality improvement projects. Customer satisfaction is measured. There is a close contact with key customers.
Supplier relationship	A small number of suppliers are used. Suppliers are involved in product development and quality improvement projects. Suppliers are evaluated based on quality. The organization provides suppliers training and technical assistance.
Workforce management	Employees are involved in quality decisions. Employees are evaluated based on their quality performance and their contributions to quality are recognized and rewarded. Managers encourage team working. There is training on QM for managers and employees.
Quality information	Quality data are available to managers and employees. There is an effort to collect timely quality data. Quality data are used for improvement.
Product/service design	There is thorough review before production. Design teams involve people from different functions such as manufacturing, marketing, purchasing departments. Simplified design and standardization is encouraged for manufacturability.
Process management	There is emphasis on mistake-proof process design. There is consistent use of statistical process control, preventive maintenance. Managers and employees make efforts to maintain clean shop floors and meet schedules.
Six Sigma role structure	The organization uses a group of improvement specialists who are developed through Six Sigma training and certification programs. The improvement specialists are classified with different ranks based on their expertise. The specialists are assigned with specific leadership roles and responsibilities in improvement teams.
Six Sigma structured improvement procedure	There is an emphasis on following a standardized procedure in planning and conducting improvement projects or design projects. Teams apply the appropriate QM tools and techniques as prescribed in each step of the structured procedure.
Six Sigma focus on metrics	Quantitative metrics are used to measure process performance and product quality performance, and set project goals. Business-level performance measures and customer expectations are integrated with process-level performance measures.

Plan–Do–Check–Act (PDCA) cycle, but Six Sigma specifies the QM tools and techniques to use within each step, which is unique to Six Sigma (Linderman et al., 2003). The Six Sigma structured improvement procedures provide teams a methodological framework to guide them in the conduct of improvement projects (see Pande et al., 2002 or Pyzdek, 2003 for detailed explanations of the steps in these procedures). Extensive use of the Six Sigma structured procedures and the associated tools and techniques in quality improvement projects is shown to facilitate the teams in learning and knowledge acquisition (Choo et al., 2007a,b).

2.2.3. Six Sigma focus on metrics

Six Sigma emphasizes using a variety of quantitative metrics in continuous improvement, such as process Sigma measurements, critical-to-quality metrics, defect measures, and 10× improvement measures as well as traditional quality measures like process capability (Breyfogle et al., 2001; Dasgupta, 2003; Linderman et al., 2003; Pyzdek, 2003). Six Sigma metrics are used to set improvement goals (Linderman et al., 2003; Pande et al., 2002). Using objective data should reduce corporate use of political agendas to drive solutions (Brewer, 2004). As suggested by Linderman et al. (2003), using explicit, challenging goals in Six Sigma projects can increase the magnitude of improvements, reduce performance variability of the projects, and increase employees' improvement efforts and commitment to quality. Moreover, Six Sigma integrates business-level performance, process measures, and project metrics into a systematic review process so that managers can manage the organization quantitatively and translate the business strategy into tactical tasks (Barney, 2002a).

2.3. Integrating Six Sigma practices and traditional QM practices

A research model is proposed to explore relationships between the three Six Sigma practices and seven

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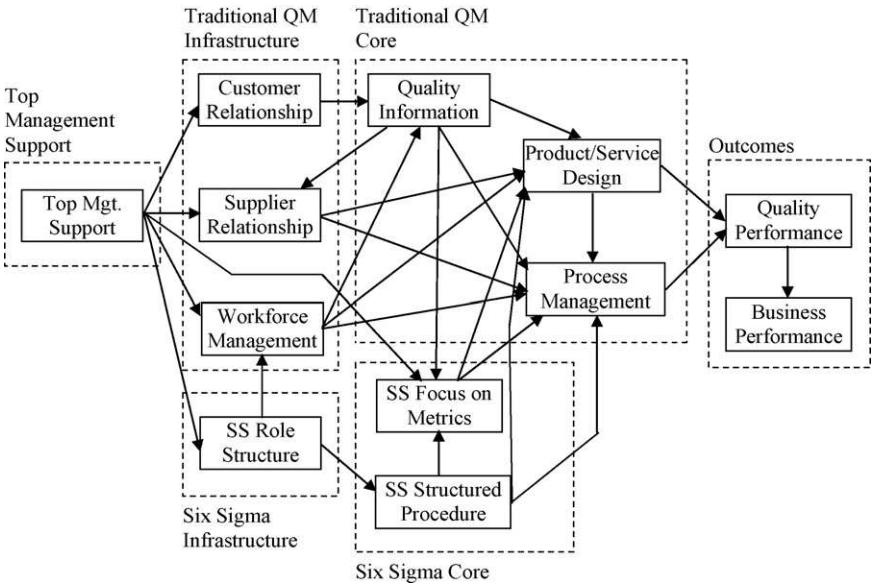

Fig. 1. Proposed model of Six Sigma practices, traditional QM practices and performance.

traditional QM practices and their effects on performance. To better illustrate the complex relationships of these practices, this study adopts the classification of infrastructure and core practices proposed by Flynn et al. (1995), where the infrastructure practices are to create an organizational environment supporting QM implementation, and the core practices focus on applying tools and techniques in continuous improvement (Flynn et al., 1995; Sousa and Voss, 2002). As shown in Fig. 1, the model starts with top management support on the left to highlight the ultimate importance of senior managers' leadership and support for QM implementation. The upper half consists of traditional QM infrastructure practices (i.e., customer relationship, supplier relationship, and workforce management) and traditional QM core practices (i.e., quality information, product/service design, and process management). The lower half presents three Six Sigma practices. Six Sigma role structure is considered as an infrastructure practice in that it is part of human resource infrastructure to assist the deployment of Six Sigma (Antony, 2004; Breyfogle et al., 2001; Henderson and Evans, 2000; Pande et al., 2002). Six Sigma structured improvement procedure and Six Sigma focus on metrics are two core practices as they represent the methodological elements of Six Sigma by emphasizing use of scientific methods, statistical tools, and quantitative metrics (Choo et al., 2007a; Linderman et al., 2006). This model suggests that the Six Sigma practices and traditional QM practices work together to improve quality performance and business performance.

2.3.1. Top management support

Top management support drives QM implementation by providing direction and resources for quality improvement (Ahire and O'Shaughnessy, 1998; Yeung et al., 2005). Top management support reflects on fostering a cooperative and learning environment needed for QM implementation (Anderson et al., 1994; Beer, 2003). The QM literature has found strong empirical support for the effects of top management support on traditional QM infrastructure practices such as customer relationship, supplier relationship, and workforce management. Top management support nurtures customer relationship by inviting customers to visit the plant and meeting with key customers, providing resources for employees to visit customer plants, requiring the collection of detailed information about customer needs and expectations, and involving customers in product design teams (Flynn et al., 1995). A long-term cooperative relationship with suppliers is possible only when top management prioritizes quality and delivery performance over price in supplier selection and retention policies, requires suppliers to be certified for quality, and provides the assessment tools for supplier quality (Flynn et al., 1995; Kaynak, 2003). Top management support facilitates workforce management by allocating resources for training, instituting a quality-based compensation policy, and

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supporting employee involvement (Ahire and O'Shaughnessy, 1998; Anderson et al., 1995; Flynn et al., 1995; Handfield et al., 1998; Kaynak, 2003). Thus, it is suggested that:

H1a. Top management support is positively related to the three traditional QM infrastructure practices.

Top management support is crucial in Six Sigma implementation, as demonstrated by chief executives such as Jack Welch of GE, Bob Galvin of Motorola, and Lawrence Bossidy of AlliedSignal, who each led Six Sigma implementation in their firm (Henderson and Evans, 2000; Slater, 2000). Top management makes the strategic decisions required for Six Sigma adoption (Lee and Choi, 2006). Six Sigma role structure can only be established if top management uses its authority and power to integrate the Six Sigma black and green belt system into the organization's human infrastructure, to adjust the performance appraisal and compensation policy to incorporate Six Sigma performance, and to provide resources for Six Sigma training (Antony and Banuelas, 2002; Bhote, 2003; Breyfogle et al., 2001; Hendricks and Kelbaugh, 1998). The support of top management for Six Sigma role structure is suggested as:

H1b. Top management support is positively related to the Six Sigma role structure.

Execution of the Six Sigma focus on metrics also requires support from top management. Top management sets its organization's strategic visions and objectives (Ahire and O'Shaughnessy, 1998). When top management gives quality the highest priority possible and demonstrates its commitment to quality by providing adequate resources for quality improvement, it conveys to employees in the organization the philosophy that quality is critical (Ahire and O'Shaughnessy, 1998). Especially, a mandate from top management calling for Six Sigma helps to build the organization-wide awareness of the importance of using strict metrics and increase the employees' commitment to achieving superior quality goals (Linderman et al., 2003). Furthermore, Six Sigma emphasizes the alignment of micro tactics with macro-organizational strategy by using the Six Sigma metrics to translate the organization's strategic plans into everyday operations (Barney, 2002a). Not all processes need to operate at the Six Sigma level and the appropriate target sigma level depends on the strategic importance of the process and the cost of the improvement relative to the benefit (Linderman et al., 2003). Thus, how top management determines its organization's strategic objectives influences the metrics and goals determined for the individual improvement projects. It is then proposed that:

H1c. Top management support is positively related to the Six Sigma focus on metrics.

2.3.2. Traditional QM infrastructure practices

In order to provide products and services that meet customer needs and expectations, it is critical to establish and maintain a close relationship with customers (Hackman and Wageman, 1995). Open communication with key customers allows companies to quickly identify customers' requirements and determine whether these requirements are being met and what improvement to make (Flynn et al., 1994; Mohrman et al., 1995). The importance of having close relationships with customers is demonstrated by facilitating the collection and use of quality information. When managers and employees have direct contacts with customers, they can readily obtain first-hand information about product and service quality and use such information in making quality decision (Mohrman et al., 1995). This suggests that:

H2a. Customer relationship is positively related to quality information.

The creation of a partnership with key suppliers is one major intervention that companies should make to realize continuous improvement (Hackman and Wageman, 1995). When the buying firm involves its suppliers in the product/service design process, the suppliers can provide inputs about product or component simplification and standardization and the capabilities of prospective materials and parts (Flynn et al., 1995; Forza and Flippini, 1998; Kaynak, 2003). Also, an improved supplier relationship enhances process management through timely delivery of high quality materials and parts (Kaynak, 2003). By selecting suppliers based on quality, firms encourage the suppliers to continuously improve their quality and thus provide high quality parts, which helps to reduce process variability due to purchased materials and parts (Flynn et al., 1995). Thus, it is suggested that:

H2b. Supplier relationship is positively related to product/service design.

H2c. Supplier relationship is positively related to process management.

Workforce management develops competent and committed employees who are loyal to the organization's goals of quality improvement (Flynn et al., 1994).

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This practice includes a variety of human resource management techniques including employee training in QM principles and methods (Flynn et al., 1995; Kaynak, 2003; Sila and Ebrahimpour, 2005), employee involvement in quality decisions (Ahire et al., 1996; Choi, 1995), recognition and compensation of employees' contribution to quality improvement (Daft, 1998), teamwork to solve problems (Daft, 1998; Flynn et al., 1995), communication to create an awareness of organizational goals (Daft, 1998; Kaynak, 2003), and employee fulfillment through pride in workmanship, job satisfaction and job commitment (Anderson et al., 1994, 1995). With a well-trained and motivated workforce, a firm is more likely to effectively improve its operations. There is empirical evidence suggesting that workforce management directly affects the application of the three traditional QM core practices. For example, workforce management facilitates collection and use of quality information by increasing employees' continuous awareness of quality-related issues (Kaynak, 2003) and empowering employees in quality decision-making (Flynn et al., 1995). The success of quality improvement efforts in product/service design and process management is dependent on the effectiveness of the actual usage of QM tools, which is ensured by management providing employees with rigorous training and encouraging them to use the tools in their job (Ahire and Dreyfus, 2000). Workforce management also supports product/service design and process management by promoting a team problem-solving approach so that people from diverse parts of the organization can provide inputs, which helps to improve the manufacturability of the designed products and to make process improvement proposals (Flynn et al., 1995; Sila and Ebrahimpour, 2005). Hence, the following hypothesis is proposed:

H2d. Workforce management is positively related to the three traditional QM core practices.

2.3.3. Six Sigma infrastructure practice

As an infrastructure practice, the Six Sigma role structure enhances the traditional workforce management practice in five human resource management areas that are considered important for QM: human resource planning and management, employee involvement, employee performance and recognition, employee well-being and satisfaction, and employee education and training (Dean and Bowen, 1994). The Six Sigma role structure strengthens human resource planning and management by offering a mechanism for employee recruitment. QM requests firms to carefully recruit and select potential employees in terms of their task-oriented skills, their potential for working with a team, their dedication to quality, and their motivation and willingness to make improvements (Flynn et al., 1994). Six Sigma black and green belt training and certification is a useful mechanism to select and promote employees with the above characteristics (Henderson and Evans, 2000). Six Sigma role structure also encourages employees' involvement in QM, offers recognition of their good performance, and considers their interests and satisfaction. Six Sigma connects employees' promotion and rewards with the level of their Six Sigma certifications and their involvement and achievement in Six Sigma projects (Henderson and Evans, 2000; Lee and Choi, 2006), which ignites the employees' interest in quality improvement and increases their commitment to the organization's goal of high quality (Linderman et al., 2003). Furthermore, Six Sigma's differentiated training augments traditional QM training by tailoring the amount and content of training for different levels of Six Sigma specialists to match their tasks' complexity so as to increase their capabilities of solving complex problems, which helps to focus them on challenging problems and increase the magnitude of improvement efforts (Linderman et al., 2003). It thus suggests that:

H3a. The Six Sigma role structure is positively related to workforce management.

The Six Sigma role structure supports the use of Six Sigma structured improvement procedure. As the central part of Six Sigma knowledge body, the DMAIC/DMADV procedures are often used as the course outline for Six Sigma black and green belt training, which reinforces their importance. This training is given incrementally so that the trainees apply it as they learn it. For example, after learning the materials related to the 'Define' step, the trainees will apply their knowledge to define an actual project (Brewer, 2004). The intensive training teaches Six Sigma black and green belts knowledge about the structured procedures and develops their capability of applying these procedures in real projects (Hendricks and Kelbaugh, 1998). And, the black and green belts are agents of change who spread Six Sigma philosophy throughout the organization and have the responsibility to teach other employees about Six Sigma (Antony and Banuelas, 2002; Henderson and Evans, 2000). Their leadership in the improvement teams will enhance the application of Six Sigma structured improvement procedure. This suggests that:

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H3b. The Six Sigma role structure is positively related to the Six Sigma structured improvement procedure.

2.3.4. Traditional QM core practices

The QM literature has emphasized the importance of availability, accuracy, and timeliness of quality information (Flynn et al., 1994; Forza and Flippini, 1998; Saraph et al., 1989; Sila and Ebrahimpour, 2005). Quality information means to systematically collecting data at every point in a problem-solving cycle to identify critical problems, analyze their root causes, and generate solutions (Hackman and Wageman, 1995). Effective use of quality information affects quality performance by providing accurate and timely information about product and service quality and process performance to facilitate management of supplier relationship, product/service design, and process management. To help suppliers improve quality, firms need to create a database about the suppliers' performance regarding material quality, on-time delivery, process capability, purchase costs and pricing, etc., so that managers and employees can identify and solve problems from supplied materials and parts and provide the suppliers timely and important feedbacks to improve their performance (Kaynak, 2003). Product/service design requires a wide range of quality information from purchasing, marketing, manufacturing, design, customers and suppliers in order to design quality into products (Kaynak, 2003). Process management is dependent on employees to collect and analyze data at the source to take immediate problem-solving action, to collect data about costs of poor quality (e.g., rework, scrap and warranty costs) to share feedback about quality performance, and to use control charts to identify quality problems and provide information on the areas that need improvement (Flynn et al., 1994; Kaynak, 2003). Thus, the following hypotheses are proposed:

H4a. Quality information is positively related to supplier relationship.

H4b. Quality information is positively related to product/service design.

H4c. Quality information is positively related to process management.

Systematic management of information and data resources is also important to Six Sigma, which is itself a data-driven approach to eliminating defects and wastes in business processes (Gowen and Tallon, 2005; Kwak and Anbari, 2004; Lee and Choi, 2006). Execution of the Six Sigma focus on metrics relies on the availability of accurate and timely quality information because quality metrics can only be used to reliably gauge processes and determine improvement goals when they are calculated using good data (Antony, 2004; Breyfogle et al., 2001; Henderson and Evans, 2000; Pande et al., 2002). According to Linderman et al. (2003), goal-setting starts in the early phases of a Six Sigma project with data being collected for calculation of baseline process performance measures like defects per million opportunities or Process Sigma, which will be the basis for establishing explicit goals. Accurate and timely data help to determine the appropriate improvement goals to ensure teams obtain the optimal investment of time and effort in the improvement endeavor (Linderman et al., 2003). In addition, it is necessary to have a database about current quality performance, customer needs and expectations, and firm performance to tie the process-level outputs to the market requirements and the firm's financial performance so that sufficient, better informed strategies can be made to addresses customer satisfaction and the firm's profitability. The above discussion suggests that:

H4d. Quality information is positively related to the Six Sigma focus on metrics.

Product/service design and process management are the two primary practices that directly contribute to improved quality performance as identified in the QM literature (e.g., Ahire and Dreyfus, 2000; Flynn et al., 1995; Kaynak, 2003), though they have different focuses in terms of their targets of improvement, visibility, and techniques (Ahire and Dreyfus, 2000). Product/service design focuses on improving product design performance with simplified designs and standardized components, and incorporating customer needs and expectations to reduce engineering changes and quality problems, which will reduce the costs of scrap and rework, increase product reliability, and improve customer satisfaction (Ahire and Dreyfus, 2000; Flynn et al., 1995; Forza and Flippini, 1998; Kaynak, 2003). On the other hand, process management strives for improving manufacturing techniques and processes by designing mistake-proof processes to reduce process variation (Flynn et al., 1995; Saraph et al., 1989); by using preventive maintenance to increase machine reliability and to reduce production interruptions which leads to improved productivity (Kaynak, 2003); and by identifying and correcting quality problems immediately which reduces reworks and waste (Ahire and Dreyfus, 2000; Forza and Flippini, 1998). Accordingly, the following hypotheses are proposed:

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H4e. Product/service design is positively related to quality performance.

H4f. Process management is positively related to quality performance.

Prior research also recognizes the synergy between product/service design and process management on quality improvement (Ahire and Dreyfus, 2000). Specifically, effective product/service design supports process management by designing reliable and manufactureable products and using simplified and standardized components in products, which helps to reduce process complexity and process variance and thus leads to more efficient process management (Flynn et al., 1995; Kaynak, 2003). Also, Ahire and Dreyfus (2000) suggest that in firms with good design efforts, members of cross-functional design teams often execute process improvement projects as well so that their knowledge, experience and attitudes toward teamwork, cooperation and customer focus will be extended into the on-going efforts of tracking and improving the quality of manufacturing processes. Thus, it is suggested that:

H4g. Product/service design is positively related to process management.

2.3.5. Six Sigma core practices

The Six Sigma structured improvement procedure is expected to support product/service design and process management. Both product/service design and process management practices involve using different managerial and technical tools and their effectiveness is dependent on how well teams actually use these tools (Ahire and Dreyfus, 2000). The DMAIC/DMADV procedures offer a standardized approach for the teams to follow, and prescribe appropriate tools to use at each step, as well as systematic project management tools, which enhances their problem-solving ability (Antony and Banuelas, 2002; Choo et al., 2004; Kwak and Anbari, 2004). In addition, these structured procedures guide the teams search for solutions to complicated problems by breaking complex tasks into elementary components to reduce task complexity so that the teams can be focused, which will increase their productivity (Linderman et al., 2003, 2006). Likewise, the use of Six Sigma metrics is more effective and efficient when teams follow the structured procedures in conducting Six Sigma projects. These procedures not only entail a 'measure' step to identify measurable customer requirements and to develop baseline defect measures, but also request using metrics throughout the project, e.g., from determining project goals in the 'define' step to establishing on-going process measures to continuously control the key processes in the 'control' step (Pande et al., 2002). Linderman et al. (2006) found that when teams strictly follow the DMAIC steps and faithfully complete each step, they are more likely to meet the project goals, especially those challenging goals, and to achieve improved project performance. Thus, the following hypotheses are proposed:

H5a. The Six Sigma structured improvement procedure is positively related to product/service design.

H5b. The Six Sigma structured improvement procedure is positively related to process management.

H5c. The Six Sigma structured improvement procedure is positively related to the Six Sigma focuses on metrics.

The Six Sigma focus on metrics enhances product/service design and process management by providing quantitative objective measures to examine product quality and process variability. During design for Six Sigma, teams use quantitative metrics to define and measure customer satisfaction and then incorporate the identified critical-to-customer characteristics into the design of products and production processes (Creveling et al., 2003). These metrics can be used to track the product through its entire life cycle to provide feedback about product quality. Likewise, the process improvement teams can use the metrics to evaluate the process targeted in their projects and to closely monitor the process over time, which increases the visibility of quality problems and allows the teams to quickly respond if needed (Pande et al., 2002; Snee and Hoerl, 2003). And, as Six Sigma metrics can measure different types of processes and functions, the teams may benchmark different processes to identify more improvement opportunities (Dasgupta, 2003). Moreover, as mentioned earlier, Six Sigma metrics are used to set specific goals of improvement projects. Linderman et al. (2003) suggest that using the specific goals will encourage team members to make more effort, to be more persistent in their tasks, and to focus on more relevant activities to accomplish improvement objectives. Thus, it is expected that by practicing Six Sigma focus on metrics, there will be more consistent efforts from employees to execute the activities related to improving product design quality and process quality. The effects of the Six Sigma focus on metrics on product/service design and process management are proposed as:

H5d. The Six Sigma focus on metrics is positively related to product/service design.

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H5e. The Six Sigma focus on metrics is positively related to process management.

2.3.6. Quality performance and business performance

Garvin's (1984) quality performance model suggests that quality performance affects business performance through two routes—the manufacturing route and the marketing route (Sousa and Voss, 2002). In the manufacturing route, improved quality performance results in fewer defects, lower scrap and rework rates, less waste, and more dependable processes, which lead to lower manufacturing costs, lower warranty and liability costs, higher efficiency and productivity, and increased return on assets and profitability (Handfield et al., 1998; Kaynak, 2003; Reed et al., 1996). In the marketing route, improved quality increases customer satisfaction that leads to increased sales and larger market share (Ahire and Dreyfus, 2000; Choi and Eboch, 1998; Handfield et al., 1998). By providing high quality products and services, the firm has less elastic demand and can charge higher prices, which brings about more profits (Kaynak, 2003; Sousa and Voss, 2002). It is thus expected that:

H6. Quality performance is positively related to business performance.

3. Research methods

3.1. Construction of survey instrument

Measures for each construct were obtained from a review of the relevant literature. Validated measures from extant empirical studies on QM were used to evaluate traditional QM practices (e.g., Anderson et al., 1995; Douglas and Judge, 2001; Flynn et al., 1994, 1995; Kaynak, 2003). Measures of quality and business performance were adapted from empirical research on QM and performance (e.g., Choi and Eboch, 1998; Douglas and Judge, 2001; Flynn et al., 1995; Kaynak, 2003; Powell, 1995; Reed et al., 1996; Samson and Terziovski, 1999). New measures were developed to evaluate three Six Sigma practices. Due to limited empirical research on Six Sigma, we reviewed both practitioner publications (e.g., Bhote, 2003; Breyfogle et al., 2001; George, 2003; Pande et al., 2000, 2002) and academic studies (Choo et al., 2004; Linderman et al., 2003; Schroeder, 2000) to create new items. Items were measured on 7-point Likert scales with end points of "strongly disagree (=1)" and "strongly agree (=7)."

The initial instrument was reviewed by faculty in operations management and strategic management for comprehensibility and accuracy. Then, the questionnaire was pre-tested by seven quality managers who had 5–20 years of experience in implementing QM in manufacturing plants. Each manager first filled out the questionnaire, and then the manager discussed with the researchers the issues including how well each scale captured the construct that it was intended to measure, whether the wording of each item was clear and understandable, and whether the format was user friendly. Using their feedback, the instrument was revised further to ensure that the questionnaire was comprehensive, understandable and valid from these experts' perspective. The items entering the survey are listed in Appendices A and B.

3.2. Data collection

A target sample of 878 US manufacturing plants (SIC codes of 20–39) was selected from the directory of the American Society for Quality (ASQ) and the Thomas Register. The research unit was an individual plant because specific QM practices are carried out at the plant level and the practices in different plants, even those within the same company, may vary substantially (Flynn et al., 1995). The respondents included plant managers, operations managers, quality managers, Six Sigma master black belts and black belts. The instrument was administered as a web-based survey. Following Dillman's (2000) total design methodology, four rounds of emails with a link to the web survey were sent to the target sample, and responses were received from a total of 226 plants resulting in an overall 26% response rate. As shown in Table 2, the sample included plants from a wide range of manufacturing industries and the majority had over 100 employees. The responding plants had been involved in a formal quality improvement effort: most plants had implemented ISO9000, TQM, and/or Six Sigma, and many plants reported that they also applied other improvement methods such as lean manufacturing, kaizen, QS9000, TS16949, or AS9100.

To assess non-response bias, this study tested the differences between the early and late respondents (Armstrong and Overton, 1977; Kaynak, 2003). The final sample was split into two, depending on the dates they were received. The early group consisted of 161 replies received before the fourth email, while the late group included 65 replies received after the fourth email. The χ^2 tests showed that there were no statistically significant differences between the two

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Table 2
The profile of the responding plants

	Number of respondents	Source	
		ASQ	ThomasNet
Industry			
Transportation equipment	73	60	13
Electrical equipment, appliance, and component	35	28	7
Fabricated metal product	23	18	5
Miscellaneous manufacturing	19	14	5
Chemical manufacturing	16	9	7
Machinery manufacturing	13	9	4
Plastics and rubber products	12	9	3
Primary metal manufacturing	9	5	4
Other industries[a]	26	22	4
Number of employees			
Less than 100	36	29	7
100–500	90	71	19
500–1000	33	21	12
More than 1000	67	53	14
Total	226	174	52

QM implementation[b]	Number of respondents	Duration of implementation[c]			
		<3 years	4–6 years	6–10 years	>10 years
ISO9000	172	18	42	56	51
TQM	91	15	14	14	43
Six Sigma	95	53	25	13	1
Other[d]	82	36	19	5	22

[a] Other manufacturing industries include food, furniture, wood product, paper, printing and related support activities, non-metallic mineral product, petroleum and coal, beverage and tobacco, and textile product mills.
[b] Many plants had implemented more than one type of QM methods.
[c] Not all plants reported the duration of their implementing ISO9000, TQM or Six Sigma, if any.
[d] Those plants reported that in addition to ISO9000, TQM, and/or Six Sigma, they applied other improvement methods as well, such as lean manufacturing, kaizen, QS9000, TS16949, or AS9100.

groups in terms of the demographic characteristics such as industry, the number of employees and the types and length of quality training the respondents received, and the *t*-tests indicated no significant differences between the means of the two groups in terms of Six Sigma practices, traditional QM practices and performance. Hence, there appeared to be no systematic response bias in the data. Also, potential bias due to two sample sources (the ASQ directory and the Thomas Register) was tested and no significant differences were found between the responses from the two different sources in terms of demographic characteristics and the level of Six Sigma and traditional QM practices and performance. Thus, there appeared to be no significant bias due to the sampling sources.

We made efforts to obtain a second response from the plants, but only 31 plants returned a second survey. Interrater agreement was assessed for the 31 dual responses using within-group agreement index $r_{wg(j)}$ and the average deviation (AD). As shown in Table 3, the $r_{wg(j)}$ value of each construct is greater than the threshold 0.70 (James et al., 1993), and the AD values range from 0.50 to 0.97, which are below the suggested upper limit of 1.20 for 7-point scales (Burke and Dunlap, 2002), both suggesting satisfactory agreement between the raters. This indicates that these dual respondents' ratings reflect their plant's attributes as opposed to their individual idiosyncratic interpretations (Henri, 2006). The 31 plants' dual responses were then averaged for the subsequent analyses.

One of the potential problems with self-reported, single-respondent data is the possibility of common method variance (CMV). Harmon's single-factor test was performed to test for the possibility of CMV in the single-respondent data of this sample (Podsakoff et al., 2003). According to the Harmon's test, if a substantial amount of CMV is present, either a single factor will emerge from the unrotated factor analysis or one

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Table 3
Descriptive statistics and interrater agreement, unidimensionality, reliability, and discriminant validity tests

Factor	Mean/S.D.	$r_{wg(j)}$	Average AD	CFI	1	2	3	4	5	6	7	8	9	10	11	12
1 Top management support	5.09/1.55	0.83	0.54	0.98	0.95[a]											
2 Customer relationship	5.71/1.17	0.87	0.50	0.99	0.56[b], 184.85[c]	0.84										
3 Supplier relationship	3.87/1.46	0.81	0.62	0.98	0.58, 190.52	0.40, 226.71	0.83									
4 Workforce management	4.98/1.38	0.83	0.63	0.94	0.77, 138.00	0.62, 156.43	0.64, 158.91	0.91								
5 Quality information	5.46/1.47	0.87	0.97	0.98	0.62, 507.58	0.55, 195.05	0.48, 236.68	0.71, 249.11	0.96							
6 Product/service design	4.67/1.45	0.82	0.67	0.99	0.68, 203.78	0.39, 241.55	0.65, 135.66	0.70, 170.65	0.55, 279.76	0.87						
7 Process management	5.04/1.19	0.80	0.60	0.93	0.71, 163.28	0.41, 229.90	0.63, 139.95	0.78, 103.92	0.69, 184.47	0.74, 102.57	0.86					
8 SS role structure	3.40/1.98	0.89	0.78	0.97	0.40, 675.72	0.18, 286.55	0.42, 253.76	0.45, 398.01	0.30, 1034.16	0.49, 311.02	0.39, 335.16	0.98				
9 SS structured procedure	4.66/1.80	0.91	0.55	0.99	0.61, 517.16	0.35, 260.64	0.60, 193.80	0.64, 290.54	0.51, 676.02	0.70, 196.63	0.58, 250.17	0.71, 659.85	0.97			
10 SS focus on metrics	4.93/1.56	0.87	0.59	0.96	0.69, 441.76	0.40, 246.69	0.57, 207.19	0.67, 268.87	0.64, 545.11	0.71, 190.58	0.68, 186.01	0.73, 641.42	0.53, 871.00	0.96		
11 Quality performance	5.14/1.20	0.91	0.53	0.98	0.65	0.46	0.61	0.63	0.53	0.63	0.70	0.58	0.40	0.79	0.93	
12 Business performance	5.21/1.45	0.90	0.54	0.95	0.42	0.24	0.34	0.43	0.31	0.35	0.38	0.38	0.40	0.50	0.59, 435.84	0.92

[a] Values on the diagonal are the composite reliability estimates.
[b] Values represent bivariate correlation for the factors.
[c] Values represent χ^2 differences between each unconstrained model and constrained model.

general factor will account for the majority of the covariance among the measures (Podsakoff et al., 2003). The three Six Sigma factors and seven traditional QM factors were each factor analyzed with the quality performance factor and the business performance factor, respectively (Kaynak and Hartley, 2006). The results show that two factors emerged for each case. To further evaluate the presence of CMV, we conducted confirmatory factor analysis (CFA) to compare χ^2 difference between a single-factor model where all the measurement items were loaded onto a single factor and a model where the measurement items were loaded onto the factor which they were intended to measure. EQS 6.1 was used throughout the study to test the CFA models and later the structural model. A significant difference (change in $\chi^2 = 3523.09$ for 66 degrees of freedom) was found between the single-factor model and the proposed model. Although the above tests do not completely eliminate the possibility of CMV, the results indicates that single-respondent, self-report bias does not appear to be a major problem in this study.

3.3. Factor analysis of Six Sigma practices and traditional QM practices

In order to examine whether the Six Sigma practices are distinct factors from the traditional QM practices, we conducted exploratory factor analysis (EFA) on the set of measurement items of the Six Sigma and traditional QM practices. EFA was run using a principal axis factoring analysis with promax rotation, and the assessment of eigenvalues and scree test indicated ten factors: the items measuring the Six Sigma practices loaded onto three factors and the items measuring the traditional QM practices loaded onto the other seven factors. The items' initial EFA loadings on their factors are shown in Appendix A.

Next, CFA was performed to further evaluate these ten factors. Multiple goodness-of-fit indices were utilized, including the ratio of χ^2 to degrees of freedom, comparative fit index (CFI), non-normed fit index (NNFI), standardized root mean square residual (SRMR) and root mean square error of approximation (RMSEA) (Kline, 2004). In the light of recommended values of fit indices (Byrne, 1998; Hu and Bentler, 1999), the ten-factor CFA model of Six Sigma and traditional QM practices had a good fit to the data: χ^2 per degree of freedom (2256.18/1494) = 1.51, less than 2; CFI = 0.92, NNFI = 0.91, both greater than 0.90; SRMR = 0.050, lower than 0.08; and RMSEA = 0.048, lower than 0.06. Thus, the above EFA and CFA results suggest that in addition to the seven traditional QM

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practices, the three Six Sigma practices identified in this study are implemented as distinctive practices in industry.

3.4. Tests for measurement model

The measurement items of Six Sigma practices, traditional QM practices, and quality and business performance were evaluated for unidimensionality, reliability and validity. For each construct, a CFA model was run to assess its unidimensionality. All the CFA models had a CFI of value higher than 0.90, indicating an adequate model fit and thus satisfactory unidimensionality of the scales (Al-Hawari et al., 2005). Composite reliability of these scales was then estimated using weighted omega, which provides a realistic reliability assessment for latent factors measured by multiple items because it considers that the items are not equally loaded onto the factor (Bacon et al., 1995). All the scales had a composite reliability estimate above 0.75, suggesting high construct reliability (Nahm et al., 2004).

Prior to testing the structural equation model, CFA was performed on the entire set of measurement items simultaneously (Anderson and Gerbing, 1988; Byrne, 1998). The measurement model was assessed by examining the goodness-of-fit indices, factor loadings, standardized residuals, and modification indices. The process of evaluating the measurement model resulted in deleting several items. These items were deleted iteratively based on the criteria such as large standardized residuals, modification indices, or factor loadings less than 0.50 (Byrne, 1998; Kaynak, 2003; Nahm et al., 2004). Before deleting a particular item, the item and respective construct were evaluated to assure that the loss of the item would not jeopardize the integrity of the construct (Nahm et al., 2004). The retained items are indicated in Appendices A and B. Unidimensionality and composite reliability of each construct were re-assessed and showed satisfactory results (Table 3). The resulting measurement model had an adequate model-to-data fit: χ^2 per degree of freedom (2128.06/1418) = 1.50, CFI = 0.92, NNFI = 0.91, SRMR = 0.050, and RMSEA = 0.047.

Based on the measurement model, convergent validity and discriminant validity were assessed. Convergent validity is demonstrated when the relationships between the items and the construct are significant, i.e., t-values are greater than 1.96 at the level of 0.05 (Al-Hawari et al., 2005). In addition, a high standardized factor loading of 0.50 or higher, ideally 0.70 or higher, provides strong evidence of convergent validity (Hair et al., 2005). In the measurement model, all the items had significant factor loadings, most of them greater than 0.70, suggesting adequate convergent validity. Discriminant validity was tested by conducting χ^2 difference tests between the constrained model that sets the correlation between any two factors at 1 and the unconstrained model that freely estimates the correlation (Anderson and Gerbing, 1988). A series of χ^2 difference tests were performed for the three Six Sigma factors and seven traditional QM factors with the significance α level adjusted to 0.0011 (0.05/45) by dividing α by the number of tests performed (Kaynak and Hartley, 2006). Similarly, discriminant validity between two performance factors was examined. In Table 3, the χ^2 difference tests between all pairs of factors are significant (a significantly lower χ^2 value for the unconstrained model), indicating strong discriminant validity (Hair et al., 2005). Additionally, an instrument has discriminant validity if the correlations between different factors are lower than the reliability coefficients (Crocker and Algina, 1986; Ghiselli et al., 1981). Table 3 shows that the correlations between the factors are all lower than their composite reliability estimates, providing further evidence of discriminant validity.

3.5. Tests for structural model

A structural model was tested to examine the relationships among Six Sigma practices, traditional QM practices and performance. The model (Fig. 2) had an adequate fit to the data: χ^2 per degree of freedom (2242.33/1458) = 1.54, CFI = 0.91, NNFI = 0.90, SRMR = 0.077, and RMSEA = 0.049. As shown in Fig. 2, the R^2 for the dependent factors range from 0.34 to 0.75, indicating that a large percentage of the variance in the dependent factors is explained by the independent factors. In the model, most proposed relationships are supported, though several relationships are not statistically significant. The non-significant relationships are those between quality information and product/service design, between quality information and process management, between Six Sigma structured procedure and product/service design, between Six Sigma structured procedure and process management, and between product/service design and process management. The implications of the test results are discussed next.

4. Discussion and conclusions

4.1. Theoretical implications

This study identified three new Six Sigma practices – the Six Sigma role structure, the Six Sigma structured

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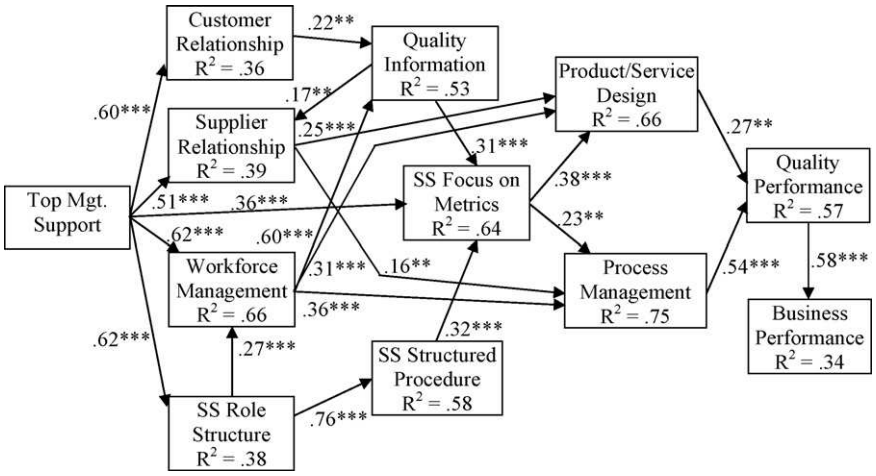

Fig. 2. Final model of Six Sigma practices, traditional QM practices and performance. $^{*}P < 0.10$, $^{**}P < 0.05$, $^{***}P < 0.01$.

improvement procedure, and the Six Sigma focus on metrics – and developed a model to investigate how these Six Sigma practices integrate with seven traditional QM practices. The findings of this study suggest a synergy between the Six Sigma practices and traditional QM practices in improving quality performance. This corroborates the view that QM practices work as an integrated, interdependent system to achieve competitive advantage (e.g., Flynn et al., 1995; Kaynak, 2003; Yeung et al., 2005). The structural model suggests important paths by which the Six Sigma practices and traditional QM practices complement each other in improving performance as discussed below.

The QM literature has unanimously emphasized the importance of top management support for QM (Beer, 2003; Yeung et al., 2005). This study once again confirms that top management support is critical for traditional QM and it is also important for Six Sigma. Top management support directly supports the Six Sigma role structure and the Six Sigma focus on metrics as well as three traditional QM infrastructure practices. The success of executing substantial changes required for Six Sigma deployment relies on whether top management understands and accepts Six Sigma principles and whether they are willing to support and enable the restructuring of the organization's policies (Antony and Banuelas, 2002; Lee and Choi, 2006).

The Six Sigma role structure's support for workforce management is a significant finding. It suggests the potential of using Six Sigma to enhance traditional human resource management practices, particularly in the areas of human resource planning and management, training, and employee recognition. Employee selection has received little attention in QM research (Dean and Bowen, 1994), however selection and planning of employees, especially leaders, for continuous improvement is critical for companies to achieve competitive advantage (Schroeder et al., 2005). Establishment of the Six Sigma role structure assists firms in recruiting the right people with the requisite technical skills and personality traits, and then developing them with training and deploying them in leadership roles with executive coaching to enhance their chances of success in quality improvement. The black and green belt system is used as a vehicle to develop the future leaders in some firms (Schroeder et al., 2005). The Six Sigma specialists have an organization-wide view of continuous improvement and an in-depth knowledge of the business processes and QM tools and methods. Such human resource is rare and difficult to imitate and thus is a critical resource for the firm to achieve sustainable competitive advantage (Barney and Wright, 1998; Gowen and Tallon, 2005; Saá-Pérez and García-Falcón, 2002).

The Six Sigma role structure also supports the structured improvement procedure. And, indirectly, through its influence on workforce management and the Six Sigma structured procedure, the Six Sigma role structure affects all three traditional QM core practices and the practice of the Six Sigma focus on metrics as well. This supports the argument that not only does Six Sigma receive support from traditional QM practices, but also it adds a new element to the QM infrastructure.

This study found that customer relationship directly affects quality information, and supplier relationship directly affects product/service design and process management. The significant relationships between

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these practices are consistent with the findings of prior studies such as Forza and Flippini (1998), Kaynak (2003), and Mohrman et al. (1995). Quality information is then found to have direct effects on supplier relationship and Six Sigma focus on metrics. These findings indicate that cooperation with external customers and suppliers continues to be very important, even with Six Sigma. Firms that focus on satisfying their customers' needs and expectations are able to collect comprehensive, accurate and timely information and use the information to generate appropriate performance measures and in working with their suppliers in product design and process improvement.

Neither quality information nor the Six Sigma structured improvement procedure has a direct effect on product/service design or process management, but those two practices are found to have a significant effect on the Six Sigma focus on metric which in turn directly affects product/service design and process management. Therefore, at the level of core practices, the Six Sigma focus on metrics mediates the effects of quality information and structured procedure on product/service design and process management. This finding highlights the importance of data and objective measurement in quality improvement. It is important to gather quality information, but this information needs to be gathered and used within an environment that values the use of objective metrics. Using the Six Sigma structured procedure ensures that teams use data and metrics during the process of solving quality problems. Moreover, such integration of Six Sigma core and traditional QM core practices corroborates the important role of goals (which is defined by various Six Sigma metrics) in continuous improvement as promoted by Linderman et al. (2003, 2006). Linderman et al. (2006) found that goals can be effective in Six Sigma improvement projects when the teams adhere to rigorous application of QM tools and method. This study further illustrates that when firms make efforts to collect accurate and timely quality data and apply the structured procedure as the paradigm of conducting improvement projects, they are more likely to better use Six Sigma metrics to monitor and motivate continuous improvement activities, which finally will lead to more effective product/service design and process management practices.

Product/service design and process management are shown to be the two practices that directly affect quality performance. This finding reinforces the suggestion by Ahire and Dreyfus (2000) that in order to achieve superior quality outcomes, firms need to balance their design and process management efforts and persevere with the long-term implementation of these efforts. However, unlike studies by Kaynak (2003) and Ahire and Dreyfus (2000), this study did not find support for the direct effect of product/service design on process management. Flynn et al. (1995) suspected that product design process would be significantly related to a measure of the degree of process control present, rather than a measure of the use of process improvement practices. However, our process management scale measured the use of various process improvement practices, which did not reflect the impact of effective design on manufacturability and process stability (Flynn et al., 1995). Additional research examining the influence of design management on process management would be valuable.

Overall, the structural model suggests the importance of a sound QM foundation for effective adoption of the new Six Sigma practices in the organization and the potential of implementing the Six Sigma practices to enhance its existing QM system. And, it shows that the Six Sigma practices and traditional QM practices work together to generate improved quality performance, which then leads to higher business performance. While there have been doubts about QM's return on the investment, more recent research found that effective implementation of QM practices will contribute to better financial, marketing, and even innovation performance by improving quality performance and/or operational performance (Kaynak, 2003; Nair, 2006; Prajogo and Sohal, 2003; Sila and Ebrahimpour, 2005; Sousa and Voss, 2002; Yeung et al., 2005). This study adds to the literature by providing further evidence that investments in QM/Six Sigma benefit an organization's bottom-line by significantly improving product and service quality.

4.2. Managerial implications

This study investigates the question about whether Six Sigma is simply a repackaging of traditional QM methods or provides a new approach to improving quality and organizational excellence. This question has created some confusion about Six Sigma (Goffnett, 2004), and also put managers in a dilemma: on one hand, if they do not adopt Six Sigma because it is considered to be the same as traditional QM methods, their company may lose the opportunity to gain substantial benefits as GE and other companies practicing Six Sigma have achieved from their Six Sigma efforts; on the other hand, if Six Sigma is different, there lacks solid answer to what are the new practices that the company needs to implement to

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improve the current QM system (Schroeder et al., 2008).

The empirical findings of this study help to clarify the relationship of Six Sigma and traditional QM. Six Sigma is grown out of traditional QM methods and many traditional QM practices are recognized as important for Six Sigma implementation (Bhote, 2003; Breyfogle et al., 2001; Gale, 2003; Henderson and Evans, 2000; Hendricks and Kelbaugh, 1998; Lee and Choi, 2006; Pyzdek, 2003; Schroeder et al., 2008). However, Six Sigma does not eliminate the traditional QM practices, nor does it simply repackage them. The conceptual foundation and the empirical evidence included in this study suggest that Six Sigma offers managers three additional practices that augment the traditional QM practices and provide new paths to quality improvement.

The three Six Sigma practices identified in this study suggests that the deployment of Six Sigma entails establishing a Six Sigma role structure within the organization's human resource management system, instituting the structured improvement procedure as a formal paradigm of conducting improvement projects, and emphasizing using quantitative objective metrics in quality improvement. Managers can use the scales developed in this study to assess the status of how each of these practice is implemented in their organization. Items in each scale of the Six Sigma practices may be used as a preliminary checklist of the important areas for the managers to address or the goals for the organization to pursue when implementing that practice.

The integrated model in this study then reveals some important areas that managers need to consider when they implement the Six Sigma practices in their organization. Top management support directly affects the implementation of Six Sigma role structure and Six Sigma focus on metrics, which suggests that for successful adoption of Six Sigma, it is critical that top management accepts the concept of Six Sigma and is willing to allocate resources to adapt the organizational structure, policies, and processes for Six Sigma. At the level of infrastructure practices, managers may complement the traditional workforce management practice with the Six Sigma role structure to augment their organization's ability in developing employees for continuous improvement. At the level of core practices, it is important to emphasize using the Six Sigma structured improvement procedure and performance metrics to motivate and guide improvement activities in product design and process management with the supply of timely and accurate quality information.

4.3. Limitations

This study is subject to several limitations. First, the majority of the data were gathered from a single respondent of each plant, and thus common method variance may be present in the results. Although statistical tests indicated that common method variance does not appear to be a major problem in this study, future work should attempt to gather data from multiple informants to provide a more accurate assessment of construct validity and the relationship of the factors (Ketokivi and Schroeder, 2004), and/or gather objective performance data when possible (Kaynak and Hartley, 2006). Second, considering that the institution of QM practices in an organization is a long-term process, the time-frame for performance measures was set to be 3-years in the questionnaire, but the data showed that while most plants responding in the survey had implemented ISO9000 and/or TQM for more than 3 years, over half of the plants practicing Six Sigma had only implemented it for less than 3 years. While this is not surprising because Six Sigma is a relatively new method, we acknowledge that the outcomes of Six Sigma implementation may not be fully revealed in the reported performance. As Six Sigma gains acceptance in industry, research can further examine the influence of Six Sigma implementation on performance by obtaining larger samples of firms with more experience on Six Sigma.

4.4. Conclusions and future research

Despite the limitations discussed above, this study contributes to the scholarly research beginning to examine Six Sigma. Schroeder et al. (2008) started with a definition of Six Sigma and its underlying theory to argue that although the Six Sigma tools and techniques appear similar to prior QM approaches, Six Sigma provides an organizational structure not previously seen. Schroeder et al. proposed that four relevant constructs or elements of Six Sigma such as parallel-meso structure, improvement specialists, structured method, and performance metrics contribute to Six Sigma's performance. Correspondingly, this study identified three Six Sigma practices which are consistent with three of the four elements suggested by Schroeder et al. (2008). Furthermore, this study used a large-scale survey to test these Six Sigma practices and their relationships with traditional QM practices, and we found empirical support for these Six Sigma constructs and their importance to QM and performance improvement, which can provide a basis for more research on Six Sigma.

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The implementation of QM in an organization requires two types of decisions: what to do and how to do it (Sousa and Voss, 2002). The findings of this study suggest that Six Sigma implementation requires three key practices to work with other QM practices in order to enhance the organization's ability of improving quality. Further research exploring how these Six Sigma practices are adopted in different organizational contexts is needed, since different organizations have different maturity levels of QM implementation and the strengths and weakness of their existing QM systems vary. It is desirable to explore the critical contextual factors influencing the integration of Six Sigma practices into an organization's existing QM system. Another area suggested for future research is the investigation of how Six Sigma works with other improvement methods such as lean manufacturing. There are common characteristics between lean manufacturing and Six Sigma in reducing waste and improving process (Breyfogle et al., 2001). As mentioned earlier, many plants sampled in this study have implemented lean manufacturing in addition to TQM or Six Sigma. Lean Six Sigma is becoming a new continuous improvement approach in industry (Devane, 2004; George, 2003). Based on the results of this study, researchers may explore how the QM/Six Sigma practices interact with lean manufacturing practices in creating a unique approach to organizational excellence.

Appendix A. Measurement scales and initial EFA factor loadings of Six Sigma and traditional QM practices

Scales and items	Initial EFA factor loadings									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Top management support (F1)										
1. *Our plant's top management (i.e. top executives and major department heads) assumes responsibility for quality performance (0.90, $t = 16.66$).	0.86									
2. *Our plant's top management provides personal leadership for quality products and quality improvement (0.93, $t = 18.39$).	0.90									
3. *Our plant's top management is evaluated for quality performance (0.85, $t = 15.28$).	0.87									
4. *Major department heads within our plant participate in the quality improvement process (0.85, $t = 15.20$).	0.85									
5. Quality issues are reviewed in our plant's management meetings.	0.74									
6. Our plant's top management has objectives for quality performance.	0.80									
Customer relationship (F2)										
1. *We frequently are in close contact with our customers (0.81, $t = 10.37$).		0.79								
2. *Our customers give us feedback on quality and delivery performance (0.79, $t = 8.54$).		0.77								
3. Our plant measures our external customers' satisfaction (customers outside the plant).		0.70								
4. We use customer requirements as the basis for quality.		0.72								
5. *Our employees know who our customers are (0.67, $t = 9.52$).		0.66								
6. *Our customers visit our plant (0.62, $t = 9.30$).		0.58								
Supplier relationship (F3)										
1. We strive to establish long-term relationships with suppliers.			0.62							
2. We rely on a small number of high quality suppliers.			0.54							
3. *Our suppliers are actively involved in our product design/redesign process (0.67, $t = 11.34$).			0.71							
4. *Our suppliers are evaluated according to quality, delivery performance, and price, in that order (0.76, $t = 14.41$).			0.71							
5. *Our plant has a thorough supplier rating system (0.80, $t = 15.87$).			0.76							

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Appendix A (*Continued*)

Scales and items	Initial EFA factor loadings									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
6. *Our suppliers are involved in our quality training (0.71, $t = 12.67$).			0.77							
7. We provide technical assistance to our suppliers.			0.80							
Workforce management (F4)										
1. *Our plant forms teams to solve problems (0.75, $t = 11.44$).				0.75						
2. Our plant gives feedback to employees on their quality performance.				0.76						
3. *Our employees are recognized for superior quality improvement (0.73, $t = 12.83$).				0.76						
4. Hourly/non-supervisory employees are involved in quality decisions.				0.80						
5. Supervisors encourage the persons who work for them to work as a team.				0.73						
6. *Quality-related training is given to hourly workers in our plant (0.87, $t = 15.79$).				0.86						
7. *Quality-related training is given to managers and supervisors in our plant (0.87, $t = 15.55$).				0.82						
8. Training is given in the "total quality concept" (i.e., philosophy of company-wide responsibility for quality) in our plant.				0.79						
9. Training is given in the basic statistical techniques (such as histogram and control charts) in our plant.				0.66						
Quality information (F5)										
1. *Quality data (error rates, defect rates, scrap, defects, cost of quality, etc.) are available in our plant (0.93, $t = 12.87$).					0.90					
2. *Quality data are available to managers, supervisors, and engineers (0.96, $t = 12.55$).					0.94					
3. *Quality data are available to hourly/non-supervisory workers (0.85, $t = 16.15$).					0.86					
4. *Quality data are timely (0.83, $t = 14.13$).					0.85					
5. Quality data are used as tools to manage quality.					0.83					
6. Quality data are used to evaluate supervisory and managerial performance.					0.63					
Product/service design (F6)										
1. *Our plant conducts a thorough review of new product/service design before the product/service is produced (0.80, $t = 13.73$).						0.83				
2. Multiple departments (such as marketing, manufacturing, and purchasing) coordinate in the product/service development process.						0.83				
3. Manufacturing and quality people are involved in the product/service development process.						0.88				
4. *Quality of new products/services is emphasized in relation to cost or schedule objectives (0.83, $t = 16.51$).						0.83				
5. *We design for manufacturability (0.76, $t = 14.01$).						0.74				
6. *We make an effort, in the design process, to list only the specifications which are clearly needed (0.72, $t = 11.24$).						0.67				
Process management (F7)										
1. Processes in our plant are designed to be "mistake-proof" to minimize the chances of errors.							0.64			
2. *We dedicate a portion of everyday solely to maintenance (0.64, $t = 10.49$).							0.51			
3. *We usually meet the production schedule everyday (0.66, $t = 9.67$).							0.42			

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Appendix A (*Continued*)

Scales and items	Initial EFA factor loadings									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
4. Production is stopped immediately for quality problems.							0.53			
5. *Our plant conducts preventive equipment maintenance (0.78, $t = 12.21$).							0.51			
6. *Clear work or process instructions are given to employees (0.82, $t = 13.33$).							0.45			
7. *Our plant's shop floors are well organized and clean (0.64, $t = 8.36$).							0.36			
8. A large number of the equipment or processes on the shop floor are currently under statistical process control.							0.85			
9. We make extensive use of statistical techniques to reduce variance in processes.							0.90			
Six Sigma role structure (F8)										
1. *We employ a black/green belt role structure (or equivalent structure) for continuous improvement (0.97, $t = 33.54$).								0.80		
2. *We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual employees for continuous improvement programs (0.98, $t = 35.09$).								0.88		
3. In our plant, members of a quality improvement team have their roles and responsibilities specifically identified.								0.89		
4. *The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of employees' training and experience (0.87, $t = 21.19$).								0.92		
5. *In our plant, an employee's role in the black/green structure (or equivalent structure) is considered when making compensation and promotion decisions (0.83, $t = 18.14$).								0.90		
6. Our plant uses differentiated training so that employees who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities.								0.60		
Six Sigma structured improvement procedure (F9)										
1. In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC—Define, Measure, Analyze, Improve and Control).									0.90	
2. *We use a structured approach to manage quality improvement activities (0.92, $t = 20.58$).									0.92	
3. *We have a formal planning process to decide the major quality improvement projects (0.94, $t = 21.09$).									0.73	
4. *All improvement projects are reviewed regularly during the process (0.95, $t = 21.91$).									0.95	
5. *We keep records about how each continuous improvement project is conducted (0.93, $t = 20.45$).									0.90	
6. In our plant, the product design process follows a formalized procedure.									0.87	
Six Sigma focus on metrics (F10)										
1. *Our plant sets strategic goals for quality improvement in order to improve plant financial performance (0.85, $t = 16.06$).										0.83
2. *Our plant has a comprehensive goal-setting process for quality (0.89, $t = 18.96$).										0.88
3. *Quality goals are clearly communicated to employees in our plant (0.91, $t = 19.83$).										0.89
4. In our plant, quality goals are challenging.										0.83
5. *In our plant, quality goals are clear and specific (0.91, $t = 17.88$).										0.91

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Appendix A (*Continued*)

Scales and items	Initial EFA factor loadings									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
6. *Our plant translates customers' needs and expectation into quality goals (0.88, $t = 17.33$).										0.87
7. We make an effort to determine the appropriate measures for each quality improvement project.										0.90
8. *In our plant, measures for quality performance are connected with the plant's strategic quality goals (0.91, $t = 19.93$).										0.93
9. The expected financial benefits of a quality improvement project are identified during the project planning phase.										0.79
10. Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant.										0.74
11. We assess the performance of core processes against customers' requirements.										0.78
12. *The measures for quality performance are connected with critical-to-quality (CTQ) characteristics (0.71, $t = 13.90$).										0.75
13. *Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate process improvements (0.79, $t = 17.15$).										0.80

The items marked with * were retained after testing the measurement models. The first value in parenthesis for each retained item indicates the standardized factor loading. The second value is the *t*-value.

Appendix B. Measurement scales for quality performance and business performance

Quality performance

1. *The quality of our plant's products and services has been improved over the past 3 years (0.85, $t = 12.15$).
2. *The process variability in our plant has decreased over the past 3 years (0.80, $t = 13.85$).
3. *The delivery of our products and services has been improved over the past 3 years (0.86, $t = 14.05$).
4. *The cost of scrap and rework as a % of sales has decreased over the past 3 years (0.77, $t = 12.80$).
5. *The cycle time (from receipt of raw materials to shipment of finished products) has decreased over the past 3 years (0.73, $t = 11.66$).
6. *Customer satisfaction with the quality of our products and services has increased over the past 3 years (0.85, $t = 14.67$).
7. *The equipment downtime in our plants has decreased over the past 3 years (0.72, $t = 11.19$).

Business performance

1. *Our plant's sales have grown over the past 3 years (0.80, $t = 11.40$).
2. *Our market share has grown over the past 3 years (0.80, $t = 11.85$).
3. The unit cost of manufacturing has decreased over the past 3 years.
4. *Our plant's operating income has grown over the past 3 years (0.91, $t = 14.45$).
5. Our plant's profits have grown over the past 3 years.
6. *Return on assets of our plant has increased over the past 3 years (0.90, $t = 16.62$).

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References

Ahire, S.L., Dreyfus, P., 2000. The impact of design management and process management on quality: an empirical examination. Journal of Operations Management 18, 549–575.

Ahire, S.L., O'Shaughnessy, K.C., 1998. The role of top management commitment in quality management: an empirical analysis of the auto parts industry. International Journal of Quality Science 31, 5–37.

Ahire, S.L., Golhar, D.Y., Waller, M.A., 1996. Development and validation of TQM implementation constructs. Decision Sciences 27, 23–56.

Al-Hawari, M., Hartley, N., Ward, T., 2005. Measuring banks' automated service quality: a confirmatory factor analysis approach. Marketing Bulletin 16, 1–19.

Anderson, J.C., Gerbing, D.W., 1988. Structural equation modeling in practice: a review and recommended two-step approach. Psychological Bulletin 103 (3), 411–423.

Anderson, J.C., Rungtusanatham, M., Schroeder, R.G., 1994. A theory of quality management underlying the Deming management method. Academy of Management Review 19, 472–509.

Anderson, J.C., Rungtusanatham, M., Schroeder, R.G., Devaraj, S., 1995. A path analytic model of a theory of quality management underlying the Deming Management Method: preliminary empirical findings. Decision Sciences 26, 637–658.

Antony, J., 2004. Some pros and cons of Six Sigma: an academic perspective. The TQM Magazine 16 (4), 303–306.

Antony, J., Banuelas, R., 2002. Key ingredients for the effective implementation of a Six Sigma program. Measuring Business Excellence 6 (4), 20–27.

Armstrong, J.S., Overton, T.S., 1977. Estimating non-response bias in mail surveys. Journal of Marketing Research 14 (3), 396–402.

Bacon, D.R., Sauer, P.L., Young, M., 1995. Composite reliability in structural equations modeling. Educational and Psychological Measurement 55, 394–406.

Barney, M., 2002a. Macro, meso, micro: Six Sigma. The Industrial-Organizational Psychologist 39 (4), 104–107.

Barney, M., 2002b. Motorola's second generation. Six Sigma Forum Magazine 1 (3), 13–16.

Barney, J.B., Wright, P.M., 1998. On becoming a strategic partner: the role of human resources in gaining competitive advantage. Human Resource Management 37, 31–46.

Beer, M., 2003. Why total quality management programs do not persist: the role of management quality and implications for leading a TQM transformation. Decision Sciences 34, 623–642.

Bhote, K.R., 2003. The Power of Ultimate Six Sigma: Keki Bhote's Proven System for Moving Beyond Quality Excellence to Total Business Excellence. AMACOM American Management Association, New York, NY.

Breyfogle, F.W., Cupello, J.M., Meadows, B., 2001. Managing Six Sigma: A Practical Guide to Understanding, Assessing, and Implementing the Strategy that Yields Bottom-line Success. John Wiley & Sons, Danvers, MA.

Brewer, P.C., 2004. Six Sigma helps a company create a culture of accountability. Journal of Organizational Excellence 23 (3), 45–59.

Burke, M.J., Dunlap, W.P., 2002. Estimating interrater agreement with the average deviation index: a user's guide. Organizational Research Methods 52, 159–172.

Byrne, B.M., 1998. Structural Equation Modeling with LISREL, PRELIS, and SIMPLIS: Basis Concepts, Application, and Programming. Lawrence Erlbaum, Mahwah, NJ.

Choi, T.Y., 1995. Conceptualizing continuous improvement: implications for organizational change. Omega 23, 607–624.

Choi, T.Y., Eboch, K., 1998. The TQM paradox: relations among TQM practices, plant performance, and customer satisfaction. Journal of Operations Management 17, 59–75.

Choo, A.S., Linderman, K., Schroeder, R.G., 2004. Social and method effects on learning behaviors and knowledge creation in Six Sigma projects. In: Proceedings of 2004 Annual Meeting of the Academy of Management, New Orleans, LA.

Choo, A.S., Linderman, K.W., Schroeder, R.G., 2007a. Method and psychological effects on learning behaviors and knowledge creation in quality improvement projects. Management Science 53 (3), 437–450.

Choo, A.S., Linderman, K.W., Schroeder, R.G., 2007b. Method and context perspectives on learning and knowledge creation in quality management. Journal of Operations Management 25 (4), 918–931.

Clifford, L., 2001. Why you can safely ignore Six Sigma. Fortune January, 140.

Creveling, C.M., Slutsky, J.L., Antis Jr., D., 2003. Design for Six Sigma in Technology and Product Development. Prentice Hall, Upper Saddle River, NJ.

Crocker, L., Algina, J., 1986. Introduction to Classical and Modern Test Theory. Harcourt, Brace and Jovanovich, Forth Worth, TX.

Daft, R.L., 1998. Organization Theory and Design. South-Western College Publishing, Cincinnati, OH.

Dalgleish, S., 2003. Six Sigma? No thanks. Quality 42 (4), 22.

Dasgupta, T., 2003. Using the six-sigma metric to measure and improve the performance of a supply chain. Total Quality Management & Business Excellence 14 (3), 355–367.

Dean, H.W., Bowen, D.E., 1994. Management theory and total quality: improving research and practice through theory development. The Academy of Management Review 19 (3), 392–418.

Devane, R., 2004. Integrating Lean Six Sigma and High-Performance Organizations: Leading the Charge Toward Dramatic, Rapid and Sustainable Improvement. Pfeiffer, San Francisco, CA.

Dillman, D.A., 2000. Mail and Internet Surveys: The Tailored Design Method. John Wiley & Sons, New York, NY.

Douglas, T.J., Judge Jr., W.Q., 2001. Total quality management implementation and competitive advantage: the role of structural control and exploration. Academy of Management Journal 44, 158–169.

Flynn, B.B., Schroeder, R.G., Sakakibara, S., 1994. A framework for quality management research and an associated measurement instrument. Journal of Operations Management 11, 339–366.

Flynn, B.B., Schroeder, R.G., Sakakibara, S., 1995. The impact of quality management practices on performance and competitive advantage. Decision Sciences 26 (5), 659–692.

Forza, C., Flippini, R., 1998. TQM impact on quality conformance and customer satisfaction: a causal model. International Journal of Production Economics 55, 1–20.

Gale, S.F., 2003. Building framework for Six Sigma. Workforce (May), 64–69.

Garvin, D., 1984. What does product quality really mean? Sloan Management Review 25–43.

George, M.L., 2003. Lean Six Sigma for Service. McGraw-Hill, New York, NY.

Ghiselli, E.E., Campbell, J.P., Zedeck, S., 1981. Measurement Theory for the Behavioral Sciences. W.H. Freeman and Company, San Francisco, CA.

Goffnett, S.P., 2004. Understanding Six Sigma: implications for industry and education. Journal of Industrial Technology 20 (4), 1–10.

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Gowen III, C.R., Tallon, W.J., 2005. Effect of technological intensity on the relationships among Six Sigma design, electronic-business, and competitive advantage: a dynamic capabilities model study. Journal of High Technology Management Research 16 (1), 59–87.

Hackman, J.R., Wageman, R., 1995. Total quality management: empirical, conceptual, and practical issues. Administrative Science Quarterly 40, 309–342.

Hair, J.F., Black, B., Babin, B., Anderson, R.E., Tatham, R.L., 2005. Multivariate Data Analysis, sixth ed. Pearson Education Prentice Hall, Upper Saddle River, NJ.

Handfield, R., Ghosh, S., Fawcett, S., 1998. Quality-driven change and its effects on financial performance. Quality Management Journal 5 (3), 13–30.

Henderson, K.M., Evans, J.R., 2000. Successful implementation of Six Sigma: benchmarking general electric company. Benchmarking: An International Journal 7 (4), 260–281.

Hendricks, C.A., Kelbaugh, R., 1998. Implementing Six Sigma at GE. The Journal of Quality and Participation 21 (4), 48–53.

Henri, J.F., 2006. Organizational culture and performance measurement systems. Accounting, Organizations and Society 31 (1), 77–103.

Hu, L., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Structural Equation Modeling 6, 1–55.

James, L.R., Demaree, R.G., Wolf, G., 1993. r_{WG}: an assessment of within-group interrater agreement. Journal of Applied Psychology 78 (2), 306–309.

Kaynak, H., 2003. The relationship between total quality management practices and their effects on firm performance. Journal of Operations Management 21 (4), 405–435.

Kaynak, H., Hartley, J.L., 2006. Using replication research for just-in-time purchasing construct development. Journal of Operations Management 24 (6), 868–892.

Ketokivi, M., Schroeder, R.G., 2004. Perceptual measures of performance: fact or fiction? Journal of Operations Management 22 (3), 247–264.

Kline, R.B., 2004. Principles and Practice of Structural Equation Modeling, second ed. The Guilford Press, New York, NY.

Kwak, Y.H., Anbari, F.T., 2004. Benefits, obstacles, and future of Six Sigma approach. Technovation 26 (5/6), 708–715.

Lee, K.C., Choi, B., 2006. Six Sigma management activities and their influence on corporate competitiveness. Total Quality Management & Business Excellence 17 (7), 893–911.

Linderman, K., Schroeder, R.G., Choo, A.S., 2006. Six Sigma: the role of goals in improvement teams. Journal of Operations Management 24 (6), 779–790.

Linderman, K., Schroeder, R.G., Zaheer, S., Choo, A.S., 2003. Six Sigma: a goal-theoretic perspective. Journal of Operations Management 21, 193–203.

Mohrman, S.A., Tenkasi, R.V., Lawler, E.E., Ledford Jr., G.G., 1995. Total quality management: practice and outcomes in the largest US firms. Employee Relations 17 (3), 26–41.

Nahm, A., Vonderembse, M., Koufteros, X., 2004. The impact of organizational culture on time-based manufacturing and performance. Decision Sciences 35 (4), 579–607.

Nair, A., 2006. Meta-analysis of the relationship between quality management practices and firm performance—implications for quality management theory development. Journal of Operations Management 24 (6), 948–975.

Pande, P.S., Neuman, R.P., Cavangh, R.R., 2000. The Six Sigma Way: How GE, Motorola, and Other Top Companies Are Honing Their Performance. McGraw Hill, New York, NY.

Pande, P.S., Neuman, R.P., Cavanagh, R.R., 2002. The Six Sigma way, Team Fieldbook: An Implementation Guide for Process Improvement Teams. McGraw-Hill, New York, NY.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y., Podsakoff, N.P., 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. Journal of Applied Psychology 88, 879–903.

Powell, T.C., 1995. Total quality management as competitive advantage: a review and empirical study. Strategic Management Journal 16, 15–37.

Prajogo, D.I., Sohal, A.S., 2003. The relationship between TQM practices, quality performance, and innovation performance: an empirical examination. International Journal of Quality & Reliability Management 20 (8), 901–918.

Pyzdek, T., 2003. The Six Sigma Handbook: A Complete Guide for Green Belts, Black Belts, and Managers at all Levels. McGraw-Hill, New York, NY.

Reed, R., Lemak, D.J., Montgomery, J.C., 1996. Beyond process: TQM content and firm performance. Academy of Management Review 21, 173–202.

Samson, D., Terziovski, M., 1999. The relationship between total quality management practices and operational performance. Journal of Operations Management 17, 393–409.

Saá-Pérez, P.D., García-Falcón, J.M., 2002. A resource-based view of human resource management and organizational capabilities development. International Journal of Human Resource Management 13 (1), 123–140.

Saraph, J.V., Benson, G.P., Schroeder, R.G., 1989. An instrument for measuring the critical factors of quality management. Decision Sciences 20, 810–829.

Schroeder, R.G., 2000. Six Sigma quality improvement: what is Six Sigma and what are the important implications? In: Proceeding of the Fourth Annual International POMS Conference, Seville, Spain.

Schroeder, R.G., Linderman, K., Zhang, D., 2005. Evolution of quality: first fifty issues of production and operations management. Production & Operations Management 14 (4), 468–481.

Schroeder, R.G., Linderman, K., Liedtke, C., Choo, A.S., 2008. Six Sigma: definition and underlying theory. Journal of Operations Management 26, 536–554.

Sila, I., Ebrahimpour, M., 2005. Critical linkages among TQM factors and business results. International Journal of Operations & Production Management 25, 1123–1155.

Sinha, K.K., Van de Ven, A.H., 2005. Designing work within and between organizations. Organization Science 16 (4), 389–408.

Slater, R., 2000. The GE Way Fieldbook: Jack Welch's Battle for Corporate Revolution. McGraw-Hill, New York, NY.

Snee, R.D., Hoerl, R.W., 2003. Leading Six Sigma: A Step-by-step Guide Based on Experience with GE and Other Six Sigma Companies. Financial Times Prentice Hall, Upper Saddle River, NJ.

Sousa, R., Voss, C.A., 2002. Quality management re-visited: a reflective review and agenda for future research. Journal of Operations Management 20, 91–109.

Stamatis, D.H., 2000. Who needs Six Sigma, anyway? Quality Digest May. Available at http://www.qualitydigest.com/may00/html/sixsigmacon.html.

Yeung, A.D.L., Cheng, T.C.E., Lai, K.H., 2005. An empirical model for managing quality in the electronics industry. Production and Operations Management 14 (2), 189–204.

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